Compressed air and microorganism growth

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Customers and users of compressed air, certainly in more critical applications, are normally in the best position to specify the required quality and purity of the utilities like compressed air.
They are consequently responsible to issue the correct specification for the supplier of compressed air equipment. The supplier, in turn, is responsible to provide equipment according to the required purity.

In hygiene critical applications like food & beverage, a compressed air pressure dew point (PDP) of -40°F/°C is very often specified.
One should understand that the energy requirement to achieve low dew points in a compressed air installation can represent a substantial part of the total energy cost. In principle, the lower the required dew point, the higher the energy demand.

To save energy in installations, it has been investigated why hygiene critical applications are specifying very often a -40°F/°C PDP, also referred as Class 2 according ISO 8573-1. Food companies have for example both direct and indirect contact compressed air usage.
Direct contact air is a process where compressed air is used as a part of the product itself, and/or the production process, including packaging and transportation of safe food production. Non-contact air is the process where compressed air is not in direct contact with the food product, however it can be, released into the local atmosphere of the food preparation, processing or storage.
The split is not always obvious.

Hygiene sensitive applications as used in Food & Beverage companies are trying to reduce the risk of microorganism growth in the final product and therefore also eliminate potential sources of contamination by utilities like compressed air. Food companies nowadays are rightfully concerned about food safety

Theory of microorganism growth and practical use of compressed air

Literature describing mechanisms of microorganism and fungi growth say:

"To support microorganism growth, it is necessary to establish conditions that will permit organism reproduction. All microorganisms require the following to remain viable and grow on culture media:

1) *Nutrients*
2) *Proper pH*
3) *Appropriate temperature*
4) *Gasses*
5) *Moisture*

1) 2) 4) are in principle not affected by the air compression process, providing that an oil-free compressor with aftercooler is used.
3) and *5)* can be linked to, or influenced by, compressing atmospheric air.

3) Appropriate Temperature
Mesophilic bacteria and fungi have an optimal growth at temperatures between 25°C/77°F and 40°C/104°F.
Thermophilic microorganisms, or heat-loving, grow at T higher than 45°C/113°F up to about 90°C/194°F.
Heat is lethal to microorganisms, but each species has its own heat tolerance. During a thermal destruction process, such as pasteurization, the rate of destruction is logarithmic, as is their rate of growth. Thus, bacteria subjected to heat are killed at a rate that is proportional to the number of organism's present. The process is dependent both on the temperature of exposure and the time required at this temperature to accomplish the desired rate of destruction. The high temperature in oil-free compression elements (>180°C/356°F) is high

enough to significantly reduce the present microorganisms. However, the time that the air is at this high temperature in the compressor parts is too short to be considered as sterilizing.

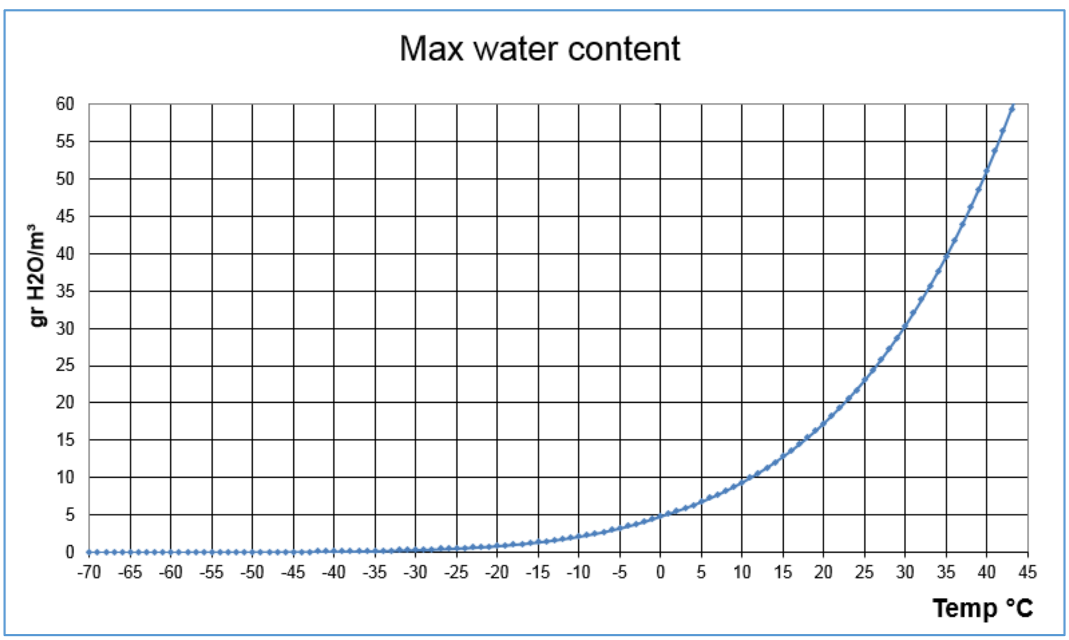
A decreasing temperature on the other hand, specifically below 18°C/64°F, is also reducing the growth activity. Microorganism activity comes almost to a stop around the freezing point of water.
Studies have indicated that the growth of microorganism (fungus and bacteria) is also considered to be on full hold when the temperature is below -10°C/14°F to -18°C/0°F depending the organism. *(ref 1)*

5) Moisture
It depends on the specific type of fungus or bacteria how much water (vapor) they need to reproduce or grow; however, all need some form of water to reproduce. The majority requires a RH of 75% or more.
Some can survive and multiply in > 50% RH. Below this relative humidity, or $a_w < 0.5$ (Ref 2 water activity), there is normally no microbial proliferation.

In other words, decreasing temperatures and moisture, or relative humidity, are both reducing the possibility for creating a viable atmosphere for microorganisms.

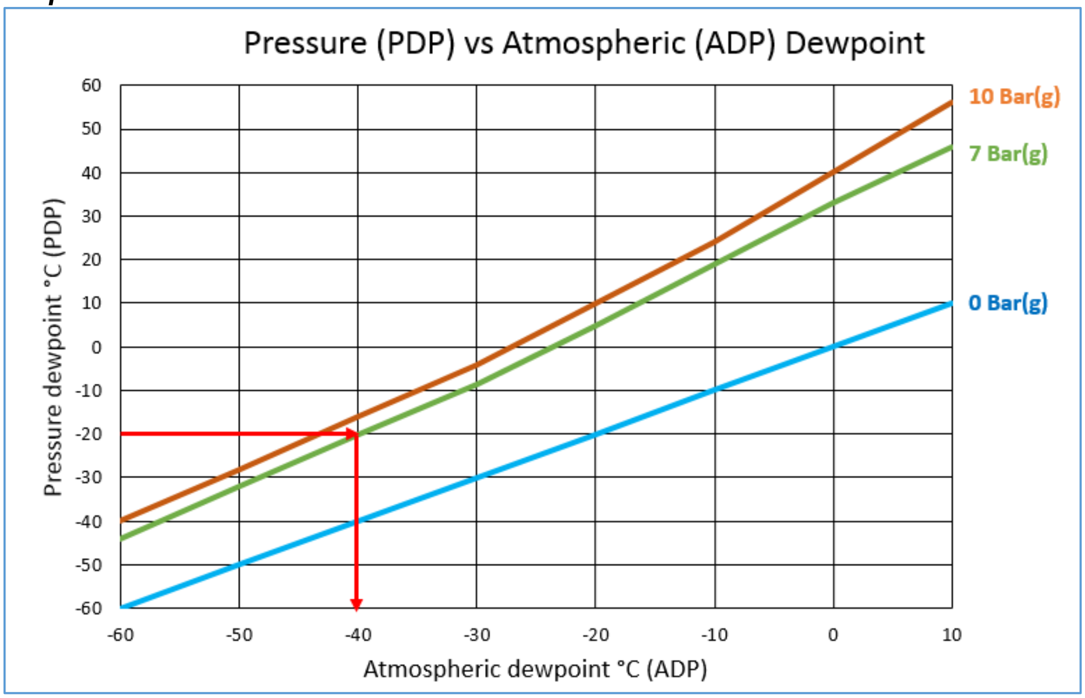
Dew point definition

Dew point temperature or dewpoint is the temperature at which a given concentration of water vapor in air will form dew or in other words it is the temperature to which air must be cooled to reach saturation. It is a measure of moisture in the air.
A dewpoint is expressed as a temperature on the scale °C or °F, and can also be seen as the maximum water content, in gr. or oz., for a standard volume of air at that given temperature.
The difference between -40°C / -40°F and -20°C / -4°F may look significant on the temperature scale, however the absolute difference of water content in gr. or oz. is marginal.



Something to consider is that very often when specifying compressed air, PDP or Pressure Dew Point is specified. Which means the maximum water content in the compressed air, under pressurized conditions.
If the air comes in contact with the product after expansion, which is in most cases the situation, the dew point or water content will be significant lower.
The present humidity will be reduced with a factor: *P(absolute) / P(atmosphere)*. (see Graph G1)
In this case the ADP (Atmospheric Dew Point) is more relevant.

Graph G1



Example: -20°C / -4°F PDP @ 7barg/102psig equals -41°C / -42°F ADP

Dew point and relation to Relative Humidity

Considering 2 situations:

1) Ambient temperature +20°C / 68°F with a Relative Humidity of 70%.

The atmospheric intake air has a water content of 12 grH2O/m^3.
The line pressure after compressor and dryer is 7 Bar(g) with a PDP = -20°C / -4°F at ambient temperature.
In this case the Relative Humidity of compressed air in the pipe line will be 5.1% and a water content of 0.9 grH2O/m^3. After expansion the (ADP) RH will be as low as 0.64% and has 0.11grH2O/m^3

2) Ambient temperature of -15°C/5°F, RH of 85% and compressed air with pressure dew point of -30°C/-22°F.

The ambient intake air has a water content of 1,18 gr/m^3. In the compressed air after the dryer, the water content is 0.34 gr/m^3 and a RH of 24%.
Since the ambient temperature is far below the freezing point of water, there will be consequently no free water and the temperature is also too low to have affect the organisms' growth.
Once the ambient temperature is increasing, organisms can in some cases restart activity. However, if the temperature goes up the RH in the compressed air net decreases and stays far below the viable atmospheric conditions of RH<40%.

Energy efficient compressed air drying solutions

For low dew point requirements different technologies can be used like heatless twin tower desiccant dryers, heat regenerated blower type dryers, heat of compression twin tower, heat of compression rotary drum, refrigerating dryers etc.
Some drying technologies, designed to achieve a fixed and very low dew point, can consume 10 to 20% of its connected compressor power.
The yearly required energy cost for these drying technologies can represent up to 13000,-Euro per 100kW installed compressor power.

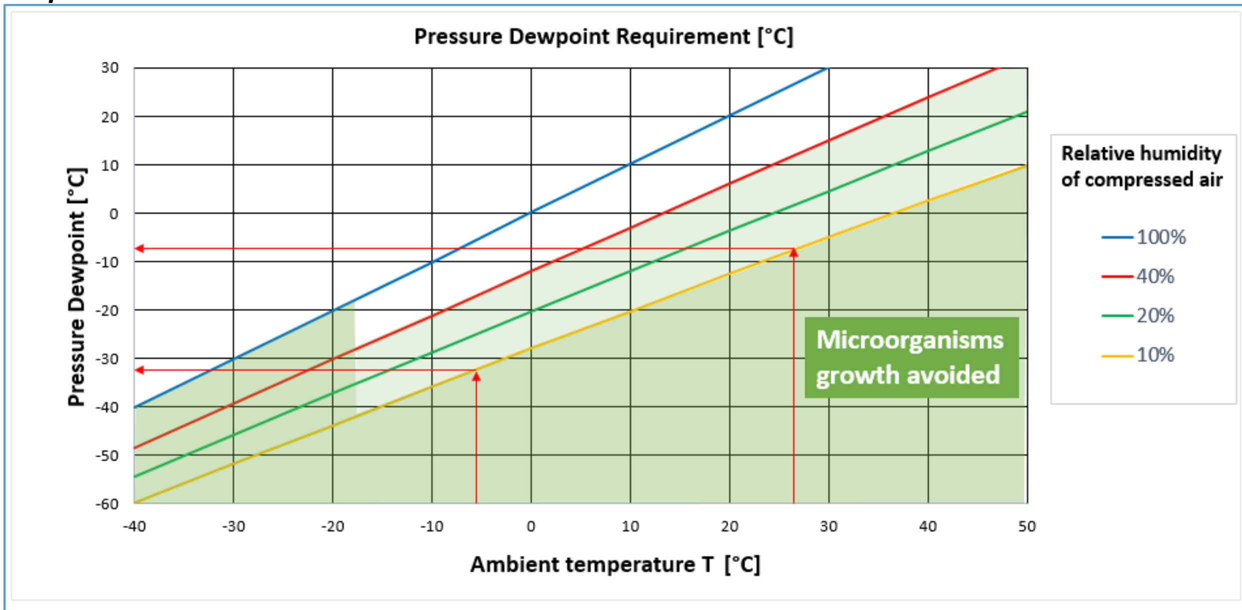
A Relative Humidity of maximum 10 to 20% is in most cases low enough to have an atmosphere in which the ability to grow and for a population of organism is avoided.
Using Relative Humidity in compressed air specification instead of PDP on the temperature scale can contribute to a hygiene safe and energy friendly installation.

Conclusion:

When specifying a pressure dew point, one should carefully set the standard, with knowledge and right motivation .
Referring to ISO 8573 PDP class 4, 3 or 2 is acceptable however the steps between respectively +3°C, -20°C and -40°C are large, certainly considering the energy requirement to achieve certain dew points.
The actual water content, which should be the decisive factor, is for temperatures below freezing point quite stable.
Significant energy savings can be achieved when the right dew point within the available drying technologies is selected and this without jeopardizing food safety or creating hygiene hazardous condition.

Microorganisms need water to grow in food products. The control of the moisture content in foods is one of the oldest exploited preservation strategies. Food microbiologists generally describe the water requirements of microorganisms in terms of the water activity (aw) of the food or environment. *(Ref 3)*
It's important to make a distinction between bacteria and molds. For bacteria a minimum of aw of 0.75 (RH 75%) is generally accepted (Staphylococcus aureus). For molds a minimum aw 0.6 (RH 60%) is considered as safe limit (Xeromyces) *(Ref 4).*
A specification of PDP RH ≤10% or even ≤ 20% can consequently be considered as food and hygiene safe.
Based on below graph (G2), one can calculate the required dew point to achieve a specific aw (RH) in the compressed air at a given ambient temperature.

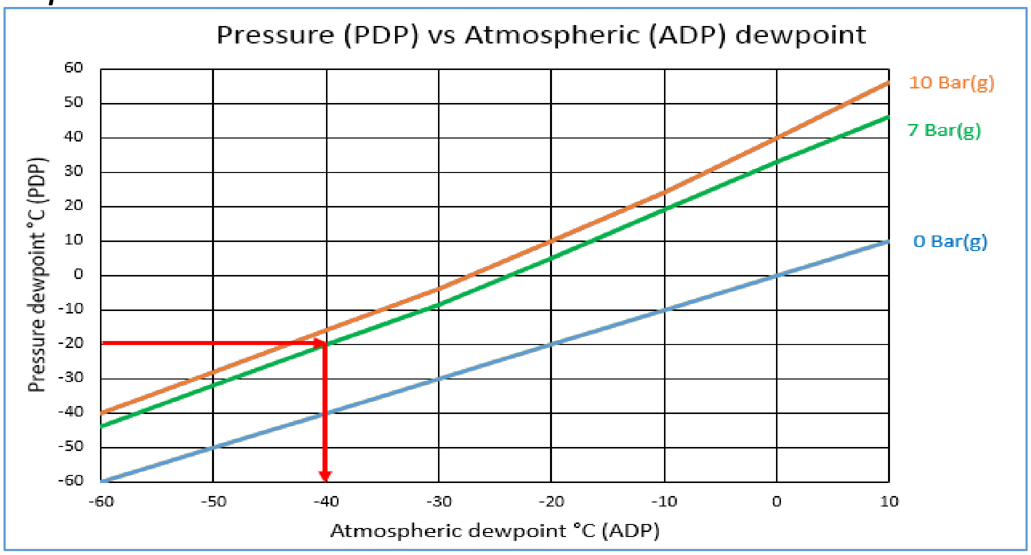
Graph G2



(1) Compressed air is assumed to be cooled down to ambient temperature
(2) Red line corresponds with minimum Pressure Dewpoint requirement to avoid bacterial growth in the compressed air
(3) At T < -18°C no microorganism activity

To calculate the corresponding atmospheric dewpoint (ADP) from a pressure dewpoint (PDP) or reverse, below graph (G3) can be used.

Graph G3



References

1) *The microbiological safety and quality of food Barbara M. Lund, A.C. Baird, Grahame W. Gould*

2) *Water activity or aw is the partial vapor pressure of water in a substance divided by the standard state partial vapor pressure of water. In the field of food science, the standard state is most often defined as the partial vapor pressure of pure water at the same temperature. Using this particular definition, pure distilled water has a water activity of exactly one. As temperature increases, aw typically increases, except in some products with crystalline salt or sugar. Higher aw substances tend to support more microorganisms. Bacteria usually require at least 0.91, and fungi at least 0.7 Rockland, L.B.; Beuchat, L.R. (1987). Water Activity:Theory and Applications to Food (2nd ed.). New York: Marcel Dekker.*

3) *Evaluation and Definition of Potentially Hazardous Foods - Chapter 3. FDA ttp://www.fda.gov/Food/FoodScienceResearch/094145.htm*

4) *Prof.Zwietering in answer to the NEN Expertgroup medical gasses 2014*